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REPORT BY THE U.S.

# General Accounting Office

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# Coal And Nuclear Wastes -- Both Potential Contributors To Environmental And Health Problems.

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The Chairman, Subcommittee on Energy Conservation and Power, House Committee on Energy and Commerce, asked GAO to answer eight questions regarding waste produced by coal and nuclear fuels during the generation of electricity. This report primarily discusses the first two items in the Chairman's request:

--What are the types and quantities of wastes generated at each step of the coal and nuclear fuel cycles?

--What are the health and environmental problems associated with these wastes?

A forthcoming report will address the Chairman's other questions, including identifying the Federal and State programs; the legal, regulatory, and technical uncertainties; and associated costs for managing and disposing of the various wastes.

Based on a comprehensive literature synthesis, GAO found that wastes produced by both the coal and nuclear fuel cycles present the potential for significant environmental and health hazards. Because the waste types present different types of hazards, however, it is not possible to determine if either waste type is more of a hazard than the other. Nonetheless, most of the hazards from both fuel cycles can be lessened, or in some cases eliminated, if properly controlled and regulated.



(14) GAO/EMD-81-132
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UNITED STATES GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

ENERGY AND MINERALS DIVISION

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B-204622

The Honorable Richard L. Ottinger
Chairman, Subcommittee on Energy
Conservation and Power
Committee on Energy and Commerce
House of Representatives

Dear Mr. Chairman:

In a letter dated July 1, 1980, the former Chairman of your Subcommittee asked us to compare the waste products from the coal and nuclear fuel cycles. The Chairman's request highlighted eight issues for our review, with emphasis on identifying the types and quantities of wastes being generated, their associated health and environmental effects, the Federal programs responsible for managing the wastes, and any technical uncertainties to disposing of the wastes. Because of this broad range of issues and the complex, technical nature of the subject, we decided, with your staff's concurrence, to divide the work and issue two reports. This report primarily discusses the first two items in the Chairman's request: (1) what are the types and quantities of wastes generated at each step of the coal and nuclear fuel cycles and (2) what are the health and environmental problems associated with these wastes? A forthcoming report will address the other six issues, including program management, regulation, and costs.

The Chairman's request was generated, in part, by the need to provide a proper perspective on the hazards associated with coal and nuclear wastes. His concern was that although much attention has been paid to nuclear wastes, little attention has been paid to the wastes resulting from the coal fuel cycle. In our view, this increased attention to nuclear wastes has led to a public perception that nuclear wastes are hazardous but that other fuel-cycle wastes, such as coal, do not present similar hazards. Thus, the purpose of this report is to provide a perspective on both coal and nuclear wastes by presenting information on the amounts and environmental and health impacts of each type of fuel within its respective fuel cycle.

Since much information has already been published on coal and nuclear wastes, we relied primarily on existing literature supplemented by interviews with officials of the appropriate

Federal agencies. We obtained over 400 reports and documents on coal and nuclear wastes, of which we selected 35 of the most current for our review. A bibliography of these reports is included as appendix III. To supplement the literature, we also interviewed officials at (1) Department of Energy offices in Germantown, Maryland, and Washington, D.C.; (2) Nuclear Regulatory Commission headquarters in Bethesda, Maryland; (3) Environmental Protection Agency headquarters in Washington, D.C.; and (4) the Edison Electric Institute's national headquarters in Washington, D.C. Thus, data provided in this report on waste quantities, potential hazards, and environmental and health effects are taken from the literature and interviews, and are not based on independent analysis by us.

Although numerous documents were available on both coal and nuclear wastes, the information on coal wastes was not as complete as that for nuclear wastes. For the most part, the literature identified nuclear waste types, quantities, and hazards, but did not clearly present this same information for coal. In fact, much of the information presented on coal wastes was speculative and not universally agreed upon. In those cases where we have discussed this type of information in appendixes I and II, we have noted that the information was either unavailable or uncertain.

Overall, the literature confirmed that wastes produced by both fuel cycles present the potential for significant environmental and health hazards. Although coal has been used considerably longer than nuclear, its environmental and health effects are not as fully understood. In fact, coal wastes were not even recognized as potentially hazardous until recent years. Thus, little information has been compiled to measure or evaluate coal waste risks. Nuclear wastes, on the other hand, were always considered potentially harmful because of their recognized radioactivity and the perceived consequences of an accident. Because of this, the possible environmental and health effects of all nuclear wastes have been carefully studied, evaluated, and documented by both the Federal Government and the nuclear industry. The biggest uncertainty with nuclear wastes is the lack of a demonstrated solution to the permanent isolation of high-level waste or spent reactor fuel. Since coal and nuclear wastes present different types of hazards and the information available on these wastes is not comparable, we did not believe it was possible to determine if either waste type is more of a hazard than the other. Nonetheless, several comparisons of the waste amounts, potential hazards, and past environmental and health effects resulting from each respective fuel cycle can be made that provide a perspective on the individual hazards of each waste type.

In short, we found that:

--The coal fuel cycle produces significantly more wastes in volume than the nuclear fuel cycle.

--Coal wastes are continually released to the environment but the resulting health effects are not fully understood.

--Nuclear wastes are significantly more toxic and radioactive than coal wastes and could pose more of a potential hazard to the environment and public health in the event of an accident.

--Nuclear wastes have been more tightly controlled and regulated than coal wastes, and therefore, have resulted in less environmental damage.

--Most of the hazards from both coal and nuclear wastes can be lessened, or in some cases eliminated, if properly controlled and regulated.

The appendixes to this letter discuss the information supporting these statements in more detail. Specifically, the appendixes identify for both the coal and nuclear fuel cycles the waste types, quantities, and potential environmental and health effects.

In June 1981, we briefed your office on the results of our review. As directed by your staff, we did not obtain comments from the various Federal agencies responsible for overseeing coal and nuclear wastes. We took this approach because the information in this report was taken from existing literature, and was not based on our independent analysis.

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As arranged with your office, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days from the date of the report. At that time, we will send copies to the Secretary of Energy, the Chairman, Nuclear Regulatory Commission, the Administrator, Environmental Protection Agency, other interested parties, and make copies available to others upon request.

Sincerely yours,

J. Dexter Peach
Director

## Contents



## ABBREVIATIONS

DOE Department of Energy

GAO General Accounting Office

NRC Nuclear Regulatory Commission

EPA Environmental Protection Agency

## THE COAL FUEL CYCLE PRODUCES

## LARGE VOLUMES OF TROUBLESOME WASTES

The coal fuel cycle--mining, cleaning, transporting, storing, and burning coal to produce electricity--results in solid wastes, liquid wastes, and gaseous and particulate emissions. Annually, approximately 400 million tons of these wastes are produced, comprised of 160 million tons of solid wastes, 5.6 million cubic meters of liquid wastes, and 230 million tons of emissions. The following table shows current and projected wastes from each fuel-cycle operation.

### Annual Quantity of Coal Wastes Generated Nationwide--Current and Projected in Year 2000

| Fuel cycle step | Waste type and quantity: Type | Current annual quantity | Projected annual quantity in year 2000 |
|---|---|---|---|
| | | (tons) | |
| Coal mining | Coal dust | 301,000 | 731,000 |
| | Solid waste piles | 43,000,000 | 123,000,000 |
| Coal cleaning | Coal dust | 174,000 | 423,000 |
| | Solid waste piles | 101,000,000 | 245,000,000 |
| Coal transportation | Coal dust | 4,000,000 | (a) |
| Coal storage | Coal dust | 742 | (a) |
| Burning coal in powerplant | Particulates | 2,585,000 | 884,000 |
| | Sulfur oxides | 17,490,000 | 14,252,000 |
| | Nitrogen oxides | 5,632,000 | 8,362,000 |
| | Carbon dioxide | 200,000,000 | 600,000,000 |
| | Hydrocarbons | 72,000 | 168,000 |
| | Bottom ash | 8,000,000 | 14,000,000 |
| | Fly ash | 46,000,000 | 79,000,000 |
| | Sludge | 6,000,000 | 33,000,000 |

a/Figures not available.

To obtain these waste quantities and other information on coal wastes, we relied heavily on existing literature supplemented by interviews with officials of appropriate Federal agencies. Based on a literature search, we obtained over 156 reports on coal wastes, of which we selected for our review those that contained the most current and thorough information on waste types, quantities, and environmental and health hazards. A bibliography of these reports is included as appendix III. To supplement the literature, we interviewed officials at (1) the Department of Energy (DOE), (2) the Environmental Protection Agency (EPA), and (3) the National Coal Association. Thus, the waste quantities and environmental and health problems identified in this report are taken from the literature and interviews, and were not independently analyzed by us.

Although an abundance of literature was available on coal wastes, the information had limitations. For the most part, the information was sufficient to identify the waste types, but was more subjective in identifying past quantities of wastes generated, past waste management practices, and specific environmental and health effects attributable to the wastes. Most of the information on these subjects was speculative and was not universally agreed upon by all sources. This was especially true with respect to environmental and health effects attributable to the various coal wastes. We believe that this has resulted because until recent years, coal wastes were not considered hazardous, and thus, adequate information was not compiled to measure quantities or evaluate risks.

Nonetheless, we feel that enough information is available from varied sources to discuss each of the issues we planned to address in this report--waste types, waste quantities, potential hazards, and suspected environmental and health problems resulting from past waste-handling operations. For some waste types, there is no universally accepted environmental or health effect. In those instances, we have tried to provide the most accepted scenario. Further, we have noted those types of wastes where the hazards are only suspected or alleged.

The following sections discuss these issues for each major type of waste in more detail.

## GASEOUS AND PARTICULATE EMISSIONS-- MAJOR CONTRIBUTORS TO ENVIRONMENTAL AND PUBLIC HEALTH PROBLEMS

When coal is burned at a powerplant, numerous gases and particles can be released into the atmosphere. These include (1) sulfur oxides, (2) nitrogen oxides, (3) carbon dioxide, (4) hydrocarbons, and (5) suspended particles. Other parts of the

coal fuel cycle result in the release of coal dust into the air. These numerous emissions may result in the most serious environmental hazards associated with the use of coal to produce electricity.

## Sulfur oxide and nitrogen oxide gases contribute to acid rain and other environmental hazards

About 17.5 million tons of sulfur oxides and 5.6 million tons of nitrogen oxides are emitted annually from powerplants in the United States. This represents about 69 percent of all sulfur oxide and 23 percent of all nitrogen oxide emissions in the United States. The remainder comes from such sources as automobile exhausts and burning of fuel for industrial, commercial, and residential uses. These gases, acting in combination or singularly, create several potential environmental and health problems. One--acid rain--can occur when either of the two gases reacts with oxygen and water to produce acidic materials, sulfates, and nitrates. These materials can be carried to earth in precipitation or as gases or particles, causing adverse environmental effects. The extent of damage due to acid precipitation, and the share of it caused by coal-burning emissions, are disputed and are currently being studied.

It is known that acid rain can increase the acidity in some lakes and rivers, and thereby, adversely affect the hatching of fish eggs and the survival of young fish. In North America, regions most threatened by acid rain include New York, part of New England, and large portions of eastern Canada. These regions have soils, and/or underlying bedrock, which are not able to neutralize acids and so are particularly vulnerable to the effects of acid rain. Increased acidity is asserted to have already resulted in approximately 100 fishless lakes in the Adirondack mountain area of New York and 140 fishless lakes in the Canadian province of Ontario, with many more lakes reportedly vulnerable. Much greater damage has been reported since the 1950s in Scandinavia. Other possible adverse effects being investigated include damage to building materials, painted surfaces, and statues; damage to crops and vegetation; reduced forest productivity; and indirect health effects through contamination of drinking water and edible fish.

A major problem in dealing with acid rain is that it apparently can occur at substantial distances from the sources of emissions. Therefore, some of the sulfur and nitrogen oxides released in one area of the country may return to earth as acid rain many hundreds of miles away. The fishless lakes in New York, for instance, have allegedly been caused in significant part by pollutants from powerplants upwind in the mid-western United States. These plants have extremely tall smoke stacks which allow the winds to carry the oxides high into the atmosphere

and away from the source of pollution. In recent testimony before the Senate Committee on Environment and Public Works, we pointed out that the current Clean Air Act does not deal very effectively with these transported pollutants.

In addition to contributing to acid rain, sulfur and nitrogen oxides are believed to contribute to other environmental and health problems. For instance, sulfur oxides have been asserted to reduce visibility, pollute the air, and contribute to severe respiratory disease. Nitrogen oxides, on the other hand, are believed to be strong eye and skin irritants and have been associated with such respiratory ailments as asthma and bronchitis and linked to localized damage to crops and forests.

Special equipment, called scrubbers, can remove an estimated 50 to 90 percent of the sulfur oxides from plant emissions, but only 30 of the 495 operating coal-fired powerplants (about 6 percent) use these collection devices. All new coal-fired plants, however, are now required under the Clean Air Act to install continuous sulfur dioxide control systems, and by 1988, 25 percent of all plants should be using scrubbers. Older plants, on the other hand, are not required to install scrubbers but instead, must continue to meet current environmental standards. These older plants, however, produce 7 times more emissions per unit of heat produced than those permissable under the requirements for new coal-fired plants. In fact, by the year 2000, if regulations are not changed, the majority of sulfur and nitrogen oxide emissions released from coal-fired powerplants will come from plants currently in operation today.

Control measures for limiting nitrogen oxide emissions are much less developed than those for sulfur oxides. In fact, emission standards are being reviewed, and research is already under way on more efficient control mechanisms. These include such things as modifying burning conditions to reduce nitrogen oxide levels and special equipment on the stacks to collect or filter the emissions.

### Carbon dioxide is suspected of causing climatic changes

Coal powerplants in the United States emit approximately 200 million tons of carbon dioxide annually. Although some of this gas is absorbed by plants and the oceans, much accumulates in the atmosphere. This could, by the beginning of the 21st century, cause a rise in the earth's temperature and many resultant environmental problems.

Recent studies have found that increased carbon dioxide emissions from coal powerplants and other sources may be one of the most serious environmental problems this country will face in the next century. They have predicted, for instance, that a

doubling of carbon dioxide in the upper atmosphere (which might occur as early as the year 2000) could cause the average global temperature to rise 1.5 to 3.0 degrees centigrade. This is due to a phenomenon commonly called the "greenhouse effect," which occurs when carbon dioxide traps heat that would otherwise radiate into space. A warmer global temperature of this magnitude could affect cloud formation, precipitation, and wind patterns which, in turn, could (1) change agricultural production areas; (2) shift the locations of grasslands, forests, deserts, and the animal life associated with those areas; and (3) cause changes in oceanic circulation.

This could have far-reaching, adverse affects on our ability to produce food, the habitability of coastal areas and cities, and the preservation of natural areas as we know them today. In particular, some studies have suggested that this rise in temperature could melt part of the solar ice regions, causing a rise in sea levels and a reduction of the earth's surface. This is a highly controversial issue, however, and has been disputed by some parts of the scientific community. For example, some scientists have theorized that dust and particles--both natural and man-made--in the atmosphere might tend to reflect incoming solar radiation and thus counteract the rise in temperature caused by carbon dioxide.

Nevertheless, carbon dioxide is considered enough of an environmental concern that alternatives should continue to be explored to reduce its buildup in the atmosphere. Unfortunately, technology does not currently exist to reduce the emissions of carbon dioxide from coal-fired powerplants. These reductions can only be done by significantly reducing the burning of fossil fuels, which may be unrealistic considering our increasing need for electricity. Several studies have suggested, therefore, that research be continued on the uncertainties associated with increased carbon dioxide in the atmosphere and on ways to limit or mitigate its effects.

### Hydrocarbons combine with nitrogen oxides to produce ozone

About 72,000 tons of hydrocarbons are emitted each year from coal-fired powerplants in the United States. These are gaseous and particulate remains of unburned fuels or compounds formed during combustion. Coal-fired plants, however, only account for about 1 percent of total hydrocarbon emissions. The rest comes predominantly from industrial processes and motor vehicles.

The primary problem with hydrocarbons is that they combine with nitrogen oxides in the presence of sunlight to form ozone.

Ozone, a major constituent of smog, is a powerful oxidizing agent which can damage crops and cause respiratory and other physical ailments. Some cities such as Los Angeles, Philadelphia, and Washington have already experienced major problems with smog, partially due to high concentrations of ozone.

Even though coal-fired plants do not contribute significantly to the hydrocarbon buildup in the atmosphere, current environmental standards limit the amounts which can be released from those plants. Complying with these standards, however, will have little affect on reducing the overall hydrocarbon levels in the atmosphere.

### Particulate emissions can cause health problems

In addition to the gases, about 2.6 million tons of solid wastes, such as fly ash and soot, are released to the atmosphere when coal is burned. These particles not only contain some radioactive elements (which are found in small quantities in most coal), but may also cause environmental and respiratory problems. For this reason, about three-fourths of all coal plants are equipped with special devices called "electrostatic precipitators," which collect from 90 to 99 percent of these particulate wastes. The remaining particles (less than 2 microns in diameter) are too small to be collected and escape into the atmosphere.

While the full extent of the health and environmental damage from these uncollected particulate emissions is not known, it is generally recognized that they are small enough to bypass the filtering mechanisms of the human respiratory tract and penetrate deeply into the lungs. If enough is inhaled, this could alter the mechanical behavior of, and reduce air flow in, the lungs. In addition, the particles may transport more toxic substances such as lead, mercury, and other suspected carcinogens which could change the cell structure in the lungs and possibly cause cancer or other respiratory ailments.

Equally as important, the solid waste particulates also contain several radioactive (and suspected cancer-causing) elements--including uranium and thorium--which are found naturally in most coal. In fact, several studies have suggested that radioactive emissions from coal-fired powerplants may be equal to or greater than those at nuclear powerplants. These radioactive elements can be transmitted to humans by (1) inhaling the ash, (2) ingesting ash-contaminated food, or (3) coming in direct contact with the particles on the ground. However, the full extent to which these particles present a long-term radiation hazard is unclear. Some sources believe that because the

particulates include long-lived radionuclides, they present a potentially serious radiation hazard. Others, however, do not believe that the amounts of radioactive emissions from coal-fired plants are enough to pose any significant health hazard.

In any event, new devices have been fabricated which will improve the collection of particulates. These devices, however, are not currently in widespread use. More importantly, the current Federal environmental standards do not specifically address fine particulate emissions. Thus, utilities are not required to install these newer devices or further control the release of fine particles.

### Coal dust reduces local air quality

Coal mining, cleaning, storing, and transporting operations release an estimated 4.5 million tons of coal dust to the atmosphere each year. The largest releases result from transporting coal to electric utilities in uncovered railroad cars, barges, and trucks. It is also released (1) during the handling of coal and coal wastes in normal mining and cleaning operations and (2) when coal is stored (in bulk) at the powerplant site to accommodate supply interruptions such as union strikes and fluctuating demand.

The most serious health effect from coal dust results when miners are exposed to heavy concentrations during underground and surface mining operations. Such exposures for extended periods of time can result in pneumoconiosis (black lung) which reduces the lung capacity of the miners and sometimes results in death from suffocation.

Otherwise, coal dust reduces air quality and may cause some health problems on a localized basis. This is more of a problem in the western United States where the arid climate and persistent high winds keep the dust suspended in the air for long periods. Wind-blown coal dust has already been linked to some crop and forest damage.

The controls for coal dust are generally governed by the requirements for particulate emissions. This limits the acceptable levels of coal dust during mining and storage operations but does little to control releases when coal is transported to the utility.

## LARGE QUANTITIES OF SOLID COAL WASTES HAVE CONTRIBUTED TO LOCALIZED ENVIRONMENTAL DAMAGE

Mining, cleaning, and burning coal produce large quantities of solid wastes. These wastes are normally piled or stored near

the site and can pollute both the air and water and threaten the health of wildlife and humans in surrounding areas. The most extensive wastes are from coal mining and cleaning operations, but large quantities of ash and other substances also result when coal is burned to produce electricity. If not effectively regulated and controlled, these wastes will continue to contribute to serious, localized environmental damage.

<u>Solid waste from coal mining and cleaning are a long-term source of water and air pollution</u>

During mining, large amounts of surrounding non-combustible rock and dirt must be removed from the mine along with the coal. This waste is normally piled next to the mine. Other types of solid waste are also accumulated during coal-cleaning operations. During this process, the mined coal is washed to remove sulfur and excess rock. This improves the coal's heat content and removes some of the impurities that can cause air pollution. The excess material separated during this stage is also usually piled near the coal operations.

Two general types of water pollution can result from solid waste piles--acid drainage and sedimentation. Acid drainage occurs when sulfuric acid (which is created when the sulfur in solid waste reacts with air and water) is washed into waterways. This acid not only damages aquatic life but can also (1) carry other toxic minerals (lead, arsenic, and copper) which, at sufficiently high levels, can threaten the people and animals that use these waters and (2) cause substantial material damage by eating away metal structures and concrete.

Sedimentation, a less severe problem, is caused when waste piles erode, forcing the sediment and dissolved solids into local waterways. This can adversely affect local aquatic life and has, in some cases, been alleged to reduce the useful life of man-made reservoirs. The problem is more significant in regions with wet climates and steep terrains.

Waste piles have already caused acid drainage and sedimentation problems in the Appalacian region extending from Pennsylvania to Alabama. In this region alone, an estimated 3,000 to 5,000 coal waste piles contain over 3 billion tons of waste, and acid drainage and sedimentation from these wastes have contaminated an estimated 10,500 miles of streams. Further, these wastes have essentially eliminated aquatic life in most of these waterways and destroyed vegetation on surrounding lands. Similar conditions are being found in some streams in the mid-west.

This, however, is not the only adverse effect of solid coal waste piles. The piles also can burn spontaneously and release

gaseous emissions to the atmosphere. These piles can burn or smolder for many years and can emit such potentially dangerous elements as carbon monoxide, nitrogen oxides, and sulfur dioxide. Such elements have damaged trees and crops, discolored paint, and adversely affected the health of people with respiratory ailments such as chronic bronchitis, asthma, or black lung disease. The full extent of these problems, however, has not been fully evaluated. EPA has reported, however, 250 million metric tons of burning waste piles in the United States at about 200 separate locations.

Federal and State programs now exist to monitor coal mining and cleaning operations and some controls have been established to minimize water and air pollution. For example, mine operators are required to use controls that will reduce the likelihood of burning waste piles, such as compacting and covering the piles. These controls are believed to help reduce air pollution from solid wastes.

Acid drainage and sedimentation of waste piles cannot be as easily controlled. Although covering and compacting the piles could lessen the effects of sedimentation and acid drainage, it is difficult to totally eliminate these problems after the mine site has been closed (short of removing all existing piles). Thus, acid drainage and sedimentation will likely continue to be a future source of water pollution.

## Solid wastes from coal combustion can pose environmental and health hazards

When coal is burned to produce electricity, three major solid waste products result--fly ash, bottom ash, and scrubber sludge. Fly ash and bottom ash are merely the non-combustible parts of coal and other unburned residuals. Scrubber sludge is the material that results from efforts to prevent sulfur oxides from being released to the atmosphere. Studies have estimated that 46 million tons of fly ash, 8 million tons of bottom ash, and 6 million tons of scrubber sludge are collected each year. These wastes are either disposed of in ponds or landfills and are suspected of causing significant environmental and health hazards.

### Fly ash

Fly ash is the fine ash removed from plant emissions by electrostatic precipitators. Besides the non-combustible parts of coal, it includes, in concentrated form, such things as sulfates, chlorides, and certain levels of toxic trace elements like mercury, lead, and zinc. In addition, fly ash includes most of the radionuclides (uranium, thorium, and radium) contained in coal. In fact, it has been found that some radioactive gases

(like radon-222) are emitted naturally from fly ash waste. Some studies suggest that this could pose a health and environmental hazard.

Because of the toxic substances found in fly ash waste, it is important that it be effectively controlled and disposed of. If not, the fly ash could leach into and contaminate surrounding ground and surface waters. In addition, the radioactive gases could contaminate areas around the disposal site. The most common disposal method today is to combine fly ash with water and discharge it into settling ponds. In many cases, however, the fly ash is disposed of in landfills or sold commercially for use in such things as cement, concrete, and bricks. In effect, utilities have been treating fly ash as a non-hazardous material. While there is no direct evidence to show that this approach is wrong, the lack of data on the contaminants in fly ash and the effect they have had on the environment has been a recent cause of concern. Consequently, EPA has initiated a study of fly ash and other coal cumbustion wastes to determine if they have been properly classified and controlled. An EPA official said that a draft report on this study is expected in the fall of 1982.

Bottom ash

Bottom ash, like fly ash, is a material which remains after coal is burned. It is heavier than fly ash, however, and settles to the bottom of the boiler rather than being blown up the stack. In addition, bottom ash does not contain the levels of toxic trace elements and other hazardous material contained in fly ash. For this reason, it is routinely removed from the plant's boiler and disposed of in settling ponds (sometimes along with fly ash) or placed in landfills. Current literature does not list any major suspected or real environmental or health problems associated with bottom ash.

Scrubber sludge

Scrubber sludge is a waste product which is collected from special powerplant emission control devices called scrubbers. These devices are designed to collect and prevent sulfur oxides from being discharged into the atmosphere. This is done by spraying the plant emissions with water or forcing them through a series of solutions. The resulting material, called sludge, includes several sulfur compounds, ash, and a variety of trace metals. Scrubber sludge is normally processed--sometimes by combining it with fly and bottom ash--and either piped or trucked to on-site settling ponds or landfills.

As with fly ash, very little information is available on the effects of scrubber sludge disposal. It is known, however, that untreated sludge, along with ash, has been dumped in unlined

ponds with very little controls. As a result, it is possible that sludge contaminants could have leached from the disposal sites and caused some degree of environmental damage. For this reason, EPA has included an analysis of scrubber sludge in its review of the classification and control of coal combustion materials.

## LIQUID COAL WASTES--LITTLE EVIDENCE OF ENVIRONMENTAL DAMAGE

Two types of liquid wastes result from coal mining and cleaning operations--slurry and sludge. Slurry is a waste solution created when coal is washed to remove non-combustible materials and other impurities. It contains fine coal particles, trace elements, and other contaminants. In most cases, slurry is piped to on-site ponds where the suspended particles are allowed to settle and the water recycled for more cleaning operations.

Sludge, also a waste solution, is formed when contaminated mine water is diverted to holding ponds and treated with lime or limestone to neutralize its acidity. As with slurry, sludge contains several contaminants and could create certain environmental problems if allowed to seep or escape from the ponds.

For the most part, detailed information on the amounts of, and problems associated with, slurry and sludge is not available. Most of the studies we examined, for instance, failed to discuss these wastes in any degree of depth, other than to mention that they could be potentially hazardous.

## THE NUCLEAR FUEL CYCLE

## PRODUCES RADIOACTIVE WASTES

Using nuclear power to generate electricity results in five basic types of radioactive wastes:

--Spent fuel--"used" reactor fuel that will be classified as a waste if not reprocessed 1/ to recover the usable uranium and plutonium.

--High-level wastes--the by-products coming out of a reprocessing plant which contain highly toxic fission products.

--Transuranic wastes--the man-made radioactive elements with half-lives of thousands of years.

--Uranium mill tailings--the sand-like radioactive wastes produced in uranium milling operations that emit low levels of radiation.

--Low-level wastes--any wastes not covered by the other categories that are contaminated with radioactive elements.

While nuclear wastes are extremely hazardous, they have been extensively studied, regulated, and controlled by both the nuclear industry and the Federal Government. Consequently, the quantities of wastes produced and their effects on the environment have generally been well documented. Because of this, we relied extensively on existing literature to identify the waste types, quantities, and potential hazards. We obtained over 250 reports on nuclear wastes, of which we selected the most current to provide the required data.

To understand these wastes properly, it is important to first understand the nuclear fuel cycle and the stages that produce the various types of wastes. Following, therefore, is a brief description of each stage of the fuel cycle and a table describing the quantities of wastes produced in each stage.

1. Mining the uranium ore and milling it to produce a more refined product called "yellow cake."

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1/Reprocessing is the process whereby the unused uranium and plutonium in spent reactor fuel can be removed for use again as nuclear reactor fuel. Since 1977, the United States has deferred indefinitely the reprocessing of commercial nuclear fuel.

2. Converting "yellow cake" to uranium hexafluoride, which is a volatile gas used in the uranium enrichment process.

3. Enriching the uranium hexafluoride to increase the fissionable uranium content from 0.7 percent, as found in nature, to between 2 and 4 percent, as required by today's nuclear reactors.

4. Fabricating uranium fuel from enriched uranium hexafluoride.

5. Operating nuclear powerplants to generate electricity.

6. Reprocessing spent reactor fuel to recover its unused uranium and plutonium content or temporarily storing it until proper disposal facilities are available.

7. Permanently disposing of radioactive wastes.

**Estimated Amounts of Nuclear Wastes Generated Nationwide**

| Fuel cycle step | Type of waste | Current annual amounts | Current cumulative amounts | Projected cumulative amounts for year 2000 |
|---|---|---|---|---|
| | | (tons) | | |
| 1. Uranium mining and milling | Uranium tailings | 10,000,000 | 35,510,260 | 400,000,000 |
| 2. Conversion | Low level | 2,530 | 6,945 | 99,208 |
| 3. Enrichment | Low level | 413 | 1,200 | 16,535 |
| 4. Fabrication | Low level | 7,771 | 30,093 | 375,668 |
| 5. Nuclear reactor operation | Spent fuel | 1,618 | 8,318 | 89,820 |
| | Low level | 71,099 | 464,624 | 3,566,528 |
| 6. Nuclear fuel reprocessing | High level | - | 3,296 | (a) |
| | Transuranic | - | 73,546 | (a) |

a/Under current U.S. policy, a moratorium on reprocessing spent reactor fuel is in effect.

Although significantly different in composition and volumes, all radioactive wastes require disposal techniques which isolate them from the human environment. Spent reactor fuel and high-level waste are intensely radioactive, pose serious environmental threats, and thus, require permanent isolation. The other wastes, while still potentially hazardous, are more easily controlled and do not require isolation for as long a period of time.

A discussion of the five waste types and their environmental and health effects follows.

## SPENT NUCLEAR REACTOR FUEL REQUIRES PERMANENT ISOLATION

Spent fuel, simply stated, is the used uranium fuel that has been removed from a nuclear reactor. It is characterized by highly penetrating and toxic radioactivity and must be isolated from the human environment for many thousands of years. Contrary to its

name, however, spent fuel is not completely "spent." It still contains significant amounts of uranium as well as plutonium which was created during the nuclear fission process. The remainder includes mostly "fission products"--such as strontium and cesium--that are also created during the fission process but which have little or no residual value.

As of December 1980, 8,318 tons of spent nuclear fuel had been removed from commercial reactors in the United States. The majority of this material is being temporarily stored in water pools at each of the Nation's 67 powerplant sites. This fuel will remain in temporary storage until it is either reprocessed or permanently placed in Federal disposal facilities.

Some of the elements of spent fuel emit high degrees of penetrating radiation and must be isolated or shielded from human contact for at least the first 1,000 years after production. The fission products, for instance, emit radiation particles which can cause serious damage to human cells and even death. Other components of spent fuel, such as uranium and plutonium, do not have such high degrees of penetrating radiation but remain potentially hazardous for millions of years. If these materials are inhaled or ingested, they are retained by the body and can cause cancer and a variety of health problems. For these reasons, spent fuel must be carefully stored and managed to ensure that the hazardous materials are properly contained and health risks minimized.

The spent-fuel storage pools were initially built to accommodate only small amounts of spent fuel. This is because the nuclear industry thought that spent fuel would remain at reactor sites for only short periods of time before being shipped to commercial reprocessing facilities. These facilities never developed as expected, however, and utilities were forced to store increasing amounts of spent fuel at the plant sites.

Although some utilities have experienced short-term storage problems, most have been able to expand the storage capacity of existing pools. According to available information, these expanded storage operations have been accomplished in a safe and acceptable manner. In fact, Nuclear Regulatory Commission (NRC) and DOE officials believe that spent fuel can be safely stored at reactor sites for at least the expected lifetime of the powerplant.

Eventually, however, spent fuel must be removed from reactor sites and transported to either reprocessing or Federal disposal facilities. Transportation mechanisms, therefore, are an important link in ensuring the continued safe management of spent

fuel. For these reasons, specially designed shipping casks have been fabricated, extensively tested, and used to safely transport spent fuel. Each cask has to meet stringent design and manufacturing requirements and must be licensed by NRC before usage. Although only small amounts of spent fuel have been shipped, available information indicates that these shipments can be made with minimum risk to the public. Nevertheless, some State and local governments remain concerned about the hazards and have restricted the trucking of spent fuel through their jurisdictions. Only recently has the Department of Transportation issued a rule preventing these types of highway restrictions on radioactive waste shipments.

If commercial spent fuel is not reprocessed, it will be disposed of in deep geological repositories. For this reason, the Federal Government is pursuing a waste management program that includes the disposal of spent fuel. From all available information, it appears that spent fuel can be safely isolated from the environment. Because of the long-lived nature of some radionuclides, however, spent fuel disposal presents some unique and difficult problems. This was the subject of a recent GAO report entitled "Is Spent Fuel or Waste from Reprocessed Spent Fuel Simpler to Dispose Of?" (EMD-81-78, June 12, 1981). In that report we concluded that the uranium and plutonium in spent fuel make its isolation in a deep geologic repository more uncertain and difficult than isolation of high-level waste.

## REPROCESSED SPENT FUEL GENERATES HIGHLY RADIOACTIVE WASTE

If spent fuel were reprocessed, it would be chemically dissolved and (through a series of complicated processes) separated into streams of uranium, plutonium, and high-level waste. The uranium and plutonium would be subsequently solidified and converted into fresh reactor fuel, while the high-level waste--along with the chemical solvents and other materials used to dissolve or process spent fuel--would remain in liquid form and be temporarily transferred to underground storage tanks close to the reprocessing installations. Eventually, it would be solidified and placed in permanent disposal facilities.

Although large quantities of high-level liquid waste have been produced in this country, most is attributable to the Government's nuclear weapons program. In fact, of the 290,000 cubic meters of high-level liquid waste currently in storage, only about 2,200 cubic meters have been produced by a commercial reprocessing facility. This facility--located in West Valley, New York--operated between 1966 and 1972 but closed when unable

to meet more stringent regulatory requirements. Since that time, no other commercial reprocessing plant has operated in this country and, given present U.S. policy, future operations are uncertain, at best. In 1977, the Carter administration proposed that commercial reprocessing be "indefinitely deferred" in this country. This policy halted construction of the Barnwell, South Carolina, reprocessing plant that was expected to begin operation in the latter part of the 1970s. This deferral occurred because of a deep concern that spent-fuel reprocessing could lead to a worldwide proliferation of nuclear weapons.

Regardless of whether additional high-level wastes are produced in the future, the existing wastes are extremely hazardous and must be permanently isolated from the environment for thousands of years. They include most of the highly toxic and radioactive fission products contained in spent fuel as well as small amounts of uranium and plutonium not removed during reprocessing operations. Also, these wastes are characterized by high levels of heat and penetrating radiation, which like spent fuel, can damage and destroy living cells, causing cancer and possibly death. Consequently, they must be carefully disposed of and managed to prevent releases to the environment and exposure to present or future generations.

Safe disposal of high-level waste, according to all available information, appears possible. DOE has a major waste management program which has already (1) selected a method for solidifying the liquid waste into glass--a step necessary before final disposal--and (2) identified the method for permanently disposing of the wastes--burial in deep geologic repositories. DOE is now attempting to identify all significant unknowns and the best possible repository sites. Among its activities, DOE is studying several types of geological media (i.e., salt, basalt, granite, and tuffs) to determine which is best suited for a repository, and canvassing the United States to find the most acceptable rock formations. DOE believes that the major obstacle to geological disposal is not the technology, but the public and political acceptance of the waste disposal concept and of the localities where the repositories will be located. Thus, DOE is also researching potential problems to resolve public fears associated with nuclear waste disposal. This will provide, under current schedules, the first geologic repository sometime between 1997 and 2006.

## SMALL AMOUNTS OF TRANSURANIC WASTE MUST BE SEGREGATED AND STORED

Transuranic waste, simply stated, is nuclear waste containing any of the 11 man-made, radioactive transuranic

elements. 1/ The primary source of this waste has been the Government's nuclear weapons program. Commercial nuclear operations, however, are producing small amounts of this waste--about 53,000 cubic feet annually--and will produce larger quantities in the future. Most of the waste produced currently is produced by industrial and Government-sponsored fuel fabrication and research activities which do not contribute to the generation of electricity. Future transuranic waste will result (1) when nuclear facilities, including nuclear powerplants, are decontaminated and decommissioned and (2) when (or if) spent nuclear fuel is reprocessed. In fact, 66,726 cubic meters of this waste was produced at the West Valley commercial reprocessing facility during its operation.

Transuranic waste primarily includes chemical process residues, discarded equipment and tools, paper, clothing, glass, and other materials that have been contaminated with transuranic elements. This waste usually generates low levels of heat but also contains long-lived radioactive elements. Because of this, transuranic waste must be disposed in a manner similar to that for high-level waste.

Until 1970, most transuranic waste was disposed in commercial and Federal shallow land burial grounds along with low-level waste. In 1970, however, the Federal Government recognized that transuranic waste could create a health hazard because it could leach out of the burial site and contaminate surrounding waterways with its long-lived radioactive elements. At that time, the Federal Government established a policy that transuranic waste must not be disposed in low-level burial grounds but should be disposed in a manner similar to that used for high-level waste. Prior to this policy change, low-level waste burial sites accepted approximately 363,000 cubic meters of transuranic-contaminated waste for burial.

Since 1970, commercial facilities have been responsible for storing small amounts of transuranic waste on-site until a permanent solution becomes available. The waste is usually placed in metal drums, stacked on asphalt pads, and then covered with dirt for later retrieval. According to DOE, storage of these small amounts of wastes has not caused any problems.

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1/Transuranic elements have an atomic number greater than 92, are artificially produced, and contain some isotopes which have radioactive half-lives of thousands of years.

## LOW-LEVEL RADIOACTIVE WASTE HAS NOT YET CAUSED SERIOUS ENVIRONMENTAL OR HEALTH PROBLEMS

Approximately 82,000 tons of low-level waste are produced annually by the various operations of the nuclear fuel cycle. Low-level waste is generally considered to be any radioactive waste that is not high-level waste, spent reactor fuel, uranium mill tailings, or transuranic waste. It may contain potentially hazardous quantities of radioactive materials in a wide range of concentrations and may also be chemically toxic. To control these radioactive materials, this waste must be properly disposed of and monitored. Problems have plagued burial sites in recent years, but according to the studies we reviewed, these problems, for the most part, have not resulted in any serious environmental or health problems.

Low-level waste is generated at all steps of the nuclear fuel cycle as solids, liquids, and gases. The principle types of wastes can be summarized as follows:

--General trash (combustible and non-combustible), which consists of contaminated material like paper, plastics, rubble, filters used in ventilation and gas-treatment systems, metal and glass items, various types of protective clothing, and miscellaneous construction and insulation materials.

--Discarded contaminated equipment, such as metal-working machinery, piping, valves, and hand tools.

--Wet waste, which includes water contaminated in various reactor operations, contaminated laundry and clean-up water, filtering aids, and sludges.

--Organic liquids, such as lubricating oils, greases, and organic solvents.

--Gaseous radioactive wastes, which are generally produced only in power reactors and are usually disposed of by discharge into the atmosphere.

All of these wastes are contaminated with potentially hazardous quantities of radioactive materials, although in a wide range of concentrations. Most lose much of their radioactivity within a few months or years; others in several hundred years. Because low-level waste contains such elements as strontium-90, which retains its radioactivity for 300 years, it must be carefully controlled and disposed of for at least that amount of time. In total, however, most low-level waste emits very little heat and most require little or no radiation shielding for handling. However, the health effects

of low levels of radiation are not fully understood. Many experiences have confirmed that ionizing radiation can increase the incidence of cancer, yet many questions remain unanswered on what amounts of radiation and what extent of contact causes it. Our recent report entitled "Problems in Assessing the Cancer Risks of Low-Level Ionizing Radiation Exposure" (EMD-81-1, Jan. 2, 1981) discusses these risks in more detail.

Solid and liquid low-level wastes require different disposal practices. Solid wastes from commercial facilities are shipped to commercial burial grounds, placed in metal drums, lowered into pits and trenches, and covered with several feet of soil. Liquid wastes, on the other hand, are either disposed of on-site in holding ponds or solidified to enable their disposal in burial grounds. Holding ponds can overflow and contaminate surrounding soil and leach into groundwater if not properly managed. However, these ponds are not expected to pose public health risks, particularly since most ponds are located in remote areas. Further, current regulations requiring periodic monitoring for releases and lining the pond reduce the likelihood of releases to surrounding water.

On the other hand, problems have plagued commercial burial grounds in recent years and have caused several sites to close. The first commercial disposal site was opened in 1962, and by 1971, six sites were licensed to dispose of low-level waste. In the last 6 years, however, three of the sites have closed. Two of these sites closed because poor trench design and site selection caused rainwater to collect in the trenches and become contaminated with radioactive elements. One of these elements--tritium--migrated off the site at both locations into surrounding surface water. The third site closure resulted when burial capacity at the site was exhausted and the operator withdrew its application to expand the site.

Of the three remaining burial facilities--located in Beatty, Nevada; Barnwell, South Carolina; and Hanford, Washington--two were temporarily shut down in recent years. Both shutdowns resulted when the Governors of Nevada and Washington became annoyed about packaging and shipping inadequacies that caused radiation leakages upon receipt of the wastes and subsequent leaching of radioactive elements in the burial sites. They, as well as the Governor of South Carolina, demanded that the rules governing shipments of commercially generated wastes be enforced. These sites have since reopened because of assurances by the Federal regulatory agencies that appropriate actions would be taken. At about the same time, the Governor of South Carolina also ordered Barnwell to reduce the amount of wastes it received by 50 percent by October 1981.

Although releases at low-level waste burial sites have occurred, the releases have not been major, and according to the

literature we reviewed, have not caused any public health problems. In addition, Federal agencies are taking actions to further reduce these releases. For example, Federal regulations now require specific packaging requirements and periodic inspections of the packages at burial sites. Also, to ensure that radiation releases are contained, Federal programs require periodic monitoring and testing of the burial grounds. Samples of soil, vegetation, wildlife, air, surface-water, and groundwater are periodically collected and analyzed to detect any radiation problems. Thus, with this type of regulation, low-level waste health problems are expected to be minimal.

## URANIUM MILL TAILINGS CAN CAUSE HEALTH HAZARDS IF NOT PROPERLY MANAGED

Uranium milling operations produce sand-like radioactive wastes--commonly called uranium mill tailings. These tailings emit low levels of radiation which can contaminate the surrounding air and waterways. Until recently, the tailings were believed to be of such low radiation that they were not considered to be harmful to the public. As a result, the tailings were often left in uncontrolled piles, exposing people to excessive levels of radiation. It is now widely recognized that mill tailings must be properly managed and disposed of to control their radiation hazard.

Compared with other types of nuclear wastes, uranium mill tailings are generated in very large volumes--about 10 to 15 million tons annually. About 15 percent of the radioactivity in uranium ore is removed with the uranium during the milling process; the remaining 85 percent remains in the tailings. Radium, the major radioactive waste product, retains its radioactivity for thousands of years and produces two potentially hazardous radiation conditions--gamma radiation and emission of gaseous radon. Excessive exposure to these radioactive elements can cause leukemia and lung cancer. Fortunately, most mills are located in remote areas where exposure is limited. Nonetheless, unless tailings piles are effectively controlled, this radioactivity can be spread to the environment by wind and water erosion, groundwater and soil contamination, and deliberate removal and unauthorized use of tailings material.

In the past, tailings were piled near the mill and abandoned. Over 24 million tons of these tailings were abandoned at 25 sites as a result of the Federal nuclear weapons program. Without knowledge of their potential radiation hazards, some of these tailings were used in the 1950s and 1960s as construction material for homes and buildings; exposing habitants to excessive levels of radiation. The Federal Government now has a program to remedy this situation by identifying and cleaning up tailings locations and facilities.

The current practice for disposing of mill tailings is to pump tailings to a holding pond constructed near the mill. In the past, tailings ponds have not been designed to prevent seepage or dam failures and have contaminated surface waters, groundwater aquifers, and wells used for irrigation and drinking. Proper siting and liners can control seepage and proper construction can prevent dam failures. Covering tailings with earth can also minimize disruption and misuse of tailings. These practices are now required by Federal programs that monitor mill tailings.

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